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# Approach statistical the underground water pollution of larbi ben m'hidi Northeast Skikda, Algeria

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**Key words:** Pollution, Underground water, Physico-chemical, Bacteriology, Larbi Ben M'hidi.

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## Abstract

This study is spread out between February 2015 and January 2016 with the purpose of a monthly sampling aimed at evaluating the hygienic quality of the well water used by the population of the Larbi Ben M'hidi region, as drinking water and domestic activities. The main physicochemical and bacteriological components of the water were measured and then a bivariate analysis consisting of calculating the linear correlation coefficient of Bravais-Pearson and a APC were performed from the average values of each parameter. A total of 168 water samples taken at the level of 07 wells likely to create a health risk for users. These wells have been identified by data sheets indicating the nature of the surrounding pollution. The samples taken were analyzed and interpreted according to the standards in force. The completed APC has been able to show very disproportionate and well-differentiated groups of stations, some of which contain medium-grade or slightly polluted wells and others which contain polluted wells. Thus, two types of pollution exist: a microbial, serious and almost permanent, coming from the runoff water and the domestic and industrial waste water, and the other chemical from weak to important for all the wells having as origin the discharges of the agricultural and / or domestic activities. The adoption by local authorities and sanitary services of a treatment by periodic chlorination of the wells used is advised, and a development and permanent control of wells, water sources near potential pollution points are recommended.

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## Introduction

Water is a necessary element for life and for real and lasting socioeconomic development of a country, it is therefore necessary to have a better knowledge on existent means in water especially concerning information, vulnerability of means to a possible mailman and necessary measurements to develop, manage and protect means. The question of the quality of water within humanitarian programs settles principally in terms of human consumption and irrigation and the poor quality of water can be led by anthropiques activities or by natural phenomena. According to the worldwide organization of health (OMS) the quality of a water is defined by physical, chemical and biological parameters, but also the usage of this water. Underground water, often protected geologically, is displayed in agrarian, industrial or urban pollutions.

The vulnerability of the tablecloth of Larbi Ben M'hidiis owed to its feeding by superficial waters, to very filterable sandy texture and to absence of cleaning up (DRE, 2015). Networks of sewers, septic pits, wastewater of plants and solid waste are the main underground sources of water pollutions in the urban area. The consumption of a water polluted by microorganisms is at the origin of epidemics (Angulo *et al.*, 1997). In addition, the nitric pollution of waters of consumption can procreate the méthémoglobinémie at the new-born babies and carcinogenic diseases at the adults (Landreau, on 1990). The present study in therefore for objective to determine in the light of results acquired from physicochemical and bacteriological parameters nature and impact of pollution on the quality of underground water of the zone of Larbi Ben M'hidi Northeast of SKIKDA.

To reach the target of this study, collected data were treated by using a combination of statistical bivariées so multivaried methods.

## Materials and methods

*Description of the zone of study*

The region of Larbi Ben M'hidi is located in 6 Km from the east of the town centre of Skikda, separated from the city by an industrial zone (ZI), included only villas in front of the sea, and big swimming pool. Under the influence of the industrialization which knew the wilaya of Skikda from 1968, a big party of a population extra wilaya and foreigner found in this small locality, the foundations of life in form of camps, with at first interim building constructed in form of wooden chalets in their majority (Hadef, on 2008) (Fig.1). Cette locality jostled by events spreads out consequently on 3120 m of coast and a complete area of 225 hectares, with a population of 9762 inhabitants (RGPH, 2005) and a park of habitat of 1860 accommodation among which more than 95 are individual (Hadef, 2008).


**Fig. 1.** Satellite Picture of the region of Skikda representing the zone of study Larbi Ben M'hidi. IZ: Industrial Zone. (Google Earth, 2016 modified).

*Choice of sampling sites*

This work is based on the waters of 07 wells of the study area (ZE) (Fig. 2), which constitute the most important water resources because they form, on the one hand, a source of domestic and Water supply and irrigation, and on the other hand a more accessible resource for the population of Larbi Ben M'hidi.

The choice of wells was made randomly and codes were assigned (Table 1).

*Sampling and transport*

Twelve (12) sampling compartments for 07 wells were carried out between February 2015 and January 2016 at the rate of one monthly sampling for 168 analyzes. Sampling for physico-chemistry was carried out in plastic bottles rinsed with distilled water and drained before being filled with a volume of one liter of water to be analyzed. The sampling for the bacteriological analyzes was carried out in 250ml glass flasks, steamed and sterilized at 220°C. At the moment of sampling, the bottle is opened with a mass to facilitate the descent into the well and to the neck a length of which depends on the depth of the well, the bottle will never be completely filled, Homogenization of the whole at the time of cultivation. The cord is then detached and the bottle is closed, labeled and placed in a low temperature cooler (4°c) to carry the samples from the study area to the laboratory.


**Fig. 2.** Representation of the study area L'arbi Ben M'hidi with the various sampling sites, P.1: Epidex wells, P.2: Refinery wells 1, P.3: Refinery wells 3, P. 4: Incisa well, P.5: Italydil well, P.6: Pritchard well, P.7: Cassis well (Google Earth, 2016 modified).

**Table 1.** Geographic Coordinates and Coding of Sampling Locations.

| Study zone | Location of Sampling | Codes | Latitudes (DSM) | Longitudes (DSM) |
|---|---|---|---|---|
| Larbi Ben M'hidi -Skikda | Wells *EPIDEX* | P1 | 36°53'13.2"N | 6°59'08.6"E |
| | Wells *RAFFINERIE* 1 | P2 | 36°53'11.9"N | 6°59'01.0"E |
| | Wells *RAFFINERIE* 3 | P3 | 36°53'13.6"N | 6°59'10.2"E |
| | Wells *INCISA* | P4 | 36°53'25.4"N | 6°59'58.6"E |
| | Wells *ITALYDIL* | P5 | 36°53'17.4"N | 6°59'27.3"E |
| | Wells *PRITCHARD* | P6 | 36°53'08.4"N | 6°59'41.1"E |
| | Wells *CASSIS* | P7 | 36°53'20.5"N | 6°59'40.4"E |

*Sample analysis*

Physical chemistry of the water was carried out with reference to Rodier *et al.* 2009, ie major elements: chlorides ($Cl^-$), calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), total hardness (TH), ammonium ($NH4^+$) and nitrite ($NO_2^-$). The temperature (T), hydrogen potential (pH), dissolved oxygen ($O_2$), turbidity (Tur) and electrical conductivity (EC) and biochemical oxygen demand ($BOD_5$) were also determined (Table 2). For bacteriology of the waters, the variation of the total bacterial population, the enumeration and the research of the bacteria of fecal origin and the research of the pathogenic bacteria are the main lines of the bacteriological analyzes of the waters (Guiraud J. P, 1998). Total coliform (CT), fecal coliform (CF) and enterococci counts were performed using the most probable number (NPP) method on BCPL and Rothe media, also referred to as Colimetry (Rejsek F, 2002) (Table 3).

*Statisticalanalyzes*

All the collected physico-chemical and bacteriological data on the groundwater of the region of Larbi Ben M'hidi was the subject of a statistical approach on the one hand by bivariate analysis which essentially consists of calculating the coefficient of correlation Linear equation of Bravais-Pearson between the variables taken two by two as much as it approaches 1 in absolute value. This coefficient is between -1 and 1 gives indices on the simultaneous evolution of the variables considered two by two. It measures the sharpness of the link existing between two series of observations insofar as this link is linear or approximately linear and on the other hand by multivariate analysis which was carried out using a Principal Component Analysis (PCA) and A Hierarchical Classification (CH) (Dagnélie, 2012). Indeed, this technique consists in transforming interrelated variables (called "correlated" in statistics) into new variables decorrelated from one another. These new variables are called "main components", or main axes.

**Table 2.** Methods of Physicochemical Analysis of Well Waters.

| Requiredparameters | Methods of analysis | References |
|---|---|---|
| Temperature | pH meter MP220 | NF T90-100 |
| *pH* | | NF T90-008 |
| Turbidity | TurbidityMeter | NF T90-033 |
| Oxygendissolved | Oximetry OXI 197 | NF T90-106 |
| Electric conductivity | Conductivitymeter 9310 | NF T90-031 |
| Total hardness and calcium | Titrimetricmethod | ISO 1984 |
| Chlorides | Volumetricmethod | Rodier 2005 |
| Nitrite and Ammonium | Spectrometric | Rodier 2005 |
| $DBO_5$ | $DBO_5$ 5-day BOD test | ISO 5815-1 |

**Table 3.** Methods of bacteriological analysis of well water.

| Enumerated or searchedgerms | Method of analysis | References |
|---|---|---|
| Total Coliforms | LiquidColimetry (NPP method) | Rodier 2005 |
| Fecalcoliforms | | |
| FecalEnterococci | | |

Statistical analysis was performed on 168 samples and 15 variables (12 physico-chemical and 03 bacteriological) using the Minitab 17 (X, 2016) software. This analysis makes it possible to synthesize and classify a large number of data in order to extract the main factors that are at the origin of the simultaneous evolution of the variables and their reciprocal relationship (Biémi, 1992).

**Results**

The results of the physicochemical and bacteriological analyzes carried out on the groundwater of the Larbi Ben M'hidi region have been presented in Table 4.

*Results of statistical analyzes*

The linear correlations obtained for the two variables taken in pairs and the values of the corresponding p-probabilities are given in Table 5. and the relationship between all variables taken in pairs and the correlation coefficients between these variables were given by the Bravais-Pearson linear correlation matrix (Table 6).

*Results of the principal component analysis (ACP) of the physico-chemical parameters of the wells*

Principal component analysis (ACP) was applied to the matrix of correlations obtained from the twelve reduced centered physico-chemical variables taken two by two. The calculations carried out give the characteristics of the 5 principal axes, the first 3 of which have an eigenvalue greater than unity or the average contribution of the different variables, ie the arithmetic mean of all the eigenvalues. These first three axes are chosen and will be used later to study the distribution of individuals (sinks) and variables in two-dimensional planes.

**Table 4.** Results of physico-chemical and bacteriological analyzes of the well water studied (Mean values).

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 |
|---|---|---|---|---|---|---|---|
| T (°C) | 18,33 | 17,5 | 18,07 | 18,33 | 17,90 | 17 | 16,97 |
| pH | 7,25 | 7,33 | 7,26 | 6,82 | 7,22 | 7,37 | 7,30 |
| CE (µs/cm) | 406,67 | 353,23 | 430,53 | 143,4 | 358,97 | 491,57 | 519,23 |
| Tur. | 0,44 | 0,20 | 0,49 | 0,28 | 0,12 | 0,58 | 0,20 |
| $O_2$ (mg/l) | 1,51 | 1,48 | 1,19 | 1,57 | 1,53 | 1,45 | 1,47 |
| TH (mg/l) | 364 | 263,33 | 259 | 249,33 | 341,33 | 304 | 248 |
| $Ca^{2+}$ (mg/l) | 132,67 | 126,67 | 125 | 220.30 | 205,67 | 170,33 | 173 |
| $Mg^{2+}$ (mg/l) | 231,33 | 136,67 | 129,67 | 144,33 | 135,67 | 133,67 | 100,33 |
| $Cl^-$ (mg/l) | 130,33 | 94,73 | 113,7 | 94,67 | 104 | 94,07 | 176,67 |
| $NO_2^-$ (mg/l) | 0.09 | 0,04 | 0,01 | 0,2 | 0.04 | 0,06 | 0,01 |
| $NH_4^+$ (mg/l) | 0,45 | 0,11 | 0,12 | 0,55 | 0,19 | 0,11 | 0,30 |
| $DBO_5$ (mg/l) | 0,50 | 0,60 | 1,10 | 0,50 | 01 | 0,50 | 0,70 |
| CT (CFU/100ml) | 7,33 | 403,33 | 3,00 | 5,33 | 19,33 | 1200,00 | 2,33 |
| CF (CFU/100ml) | 1,33 | 31,00 | 0,00 | 0,00 | 0,00 | 224,67 | 0,00 |
| Ent (CFU/100ml) | 1,33 | 3,67 | 0,00 | 10,00 | 0,00 | 913,33 | 0,00 |

T = Temperature; CE = Electrical conductivity; Tur.= Turbidity; O2 = dissolved oxygen; TH = Total Hardness; Ca + = Calcium; Mg2 + = Magnesium; Cl- = Chloride; NO2- = Nitrite; NH4 + = Ammonium; BOD5 = Biochemical Oxygen Demand; CT = Total coliforms; CF = Fecal coliforms; Ent. = Enterococci.

**Table 5.** List of significant, highly and very highly significant correlations.

| Positive correlations | | | Negativecorrelations | | |
|---|---|---|---|---|---|
| Significant | Highly significant | VeryHighly Significant | Significant | Highly significant | VeryHighly Significant |
| T and *pH* | CE and $Ca^{2+}$ | CT and CF | T and TH | T and $Ca^{2+}$ | T and CE |
| CE and TH | TH and $Mg^{2+}$ | CT and Ent. | $Ca^{2+}$ and $NO_2^-$ | $O_2$ and $DBO_5$ | TH and $NO_2^-$ |
| TH and $Ca^{2+}$ | | | | | |

**Table 6.** Matrix of linear correlations of the characteristics taken two to two.

| Variables | T pH CE Tur $O_2$ TH $Ca^{2+}$ $Mg^{2+}$Cl- $NO_2^-$ $NH_4^+$ $DBO_5$ CT CF |
|---|---|
| *pH* | 0,436* |
| | 0,048 |
| CE | -0,782*** 0,070 |
| | 0,000 0,763 |
| Tur | -0,189 -0,071 0,228 |
| | 0,412 0,759 0,319 |
| $O_2$ | 0,261 -0,100 -0,241 -0,036 |
| | 0,254 0,666 0,292 0,875 |
| TH | -0,513* -0,258 0,485* 0,268 0,002 |
| | 0,017 0,258 0,026 0,241 0,993 |
| $Ca^{2+}$ | -0,557** -0,057 0,608** 0,028 -0,166 0,502* |
| | 0,009 0,806 0,003 0,902 0,473 0,021 |
| $Mg^{2+}$ | -0,119 -0,213 0,029 0,263 0,144 0,614** -0,345 |
| | 0,607 0,354 0,899 0,249 0,532 0,003 0,126 |
| Cl- | 0,361 0,281 -0,078 -0,235 -0,018 -0,241 -0,054 -0,257 |
| | 0,108 0,217 0,736 0,304 0,937 0,292 0,816 0,262 |
| $NO_2^-$ | 0,286 -0,053 -0,423 -0,055 0,174 -0,649***-0,537* -0,229 -0,125 |
| | 0,208 0,820 0,056 0,812 0,449 0,001 0,012 0,319 0,590 |
| $NH_4^+$ | 0,088 -0,204 -0,187 -0,187 0,095 0,092 -0,258 0,344 0,066 0,040 |
| | 0,706 0,374 0,417 0,418 0,682 0,691 0,259 0,127 0,775 0,864 |
| $DBO_5$ | 0,307 0,357 -0,185 -0,167 -0,632** -0,251 0,014 -0,326 0,164 -0,019 -0,189 |
| | 0,176 0,112 0,422 0,470 0,002 0,273 0,950 0,150 0,478 0,935 0,412 |
| CT | -0,041 0,104 0,028 0,146 0,012 0,102 0,068 0,026 -0,183 0,027 0,220 -0,275 |
| | 0,859 0,652 0,903 0,528 0,960 0,661 0,768 0,910 0,426 0,907 0,338 0.227 |
| CF | 0,087 0,214 -0,041 0,007 0,124 -0,223 -0,053 -0,215 -0,019 0,148 -0,208 -0.174 0.692*** |
| | 0,709 0,352 0,861 0,977 0,593 0,330 0,820 0,350 0,935 0,521 0,364 0.450 0.001 |
| ENT | -0,269 0,091 0,290 0,433 -0,129 0,251 0,219 0,058 -0,213 -0,029 -0,215 -0.205 0.682*** 0.299 |
| | 0,237 0,694 0,202 0,050 0,577 0,272 0,340 0,802 0,354 0,901 0,350 0.373 0.001 0.188 |

***NB:*** *The values in italics correspond to the value of the probability p*

Table 7 gives the eigenvalues, the percentages of variation explained by each of the 5 axes selected, as well as the cumulative percentages. It can be seen that the first axis accounts for 42% of the total variation of the initial variables, the first 2 axes explain together 75.3%, the first 3 axes together account for 95.3%. Therefore, these 5 axes or synthetic indices summarize as much as possible the information provided by the 12 initial variables.

The numerical results of the ACP show that the first component contrasts ($Ca^{2+}$, pH and CE) with positive coordinates, with T and $NO_2^-$ having a strong contribution on the negative side.

The second component opposes DT and $Mg_2^+$, which contribute positively to the expression of this axis. In contrast to $NH_4^+$ $DBO_5$ which negatively correlate with this axis (Fig. 3A).

The hierarchical classification of the wells on the basis of the physicochemical quality of these waters allowed us to distinguish four groups of wells (Figs. 3B, 3C):

Group 1: It isolates the well P4, which has water of poor physicochemical quality, characterized by a high level of $NO_2^-$ and also of $NH_4^+$. This could be explained by the human and agricultural activities neighboring this water point.

Group 2: This group consists of two wells, P6 and P3, whose waters are of medium physicochemical quality. Group 3: This group brings together two wells P7 and P2, which has water of good physicochemical quality.

Group 4: This group assembles two wells P5 and P1, whose waters are of medium physicochemical quality but characterized in very high magnesium ions.

**Table 7.** Eigenvalues and percentages expressed for the main axes.

| Parameter | Axis 1 | Axis 2 | Axis 3 |
|---|---|---|---|
| Own values | 2,0983 | 1,6652 | 1,0013 |
| Percentageexplained in % | 0,420 | 0,333 | 0,200 |
| Percentage cumulative in% | 0,420 | 0,753 | 0,953 |

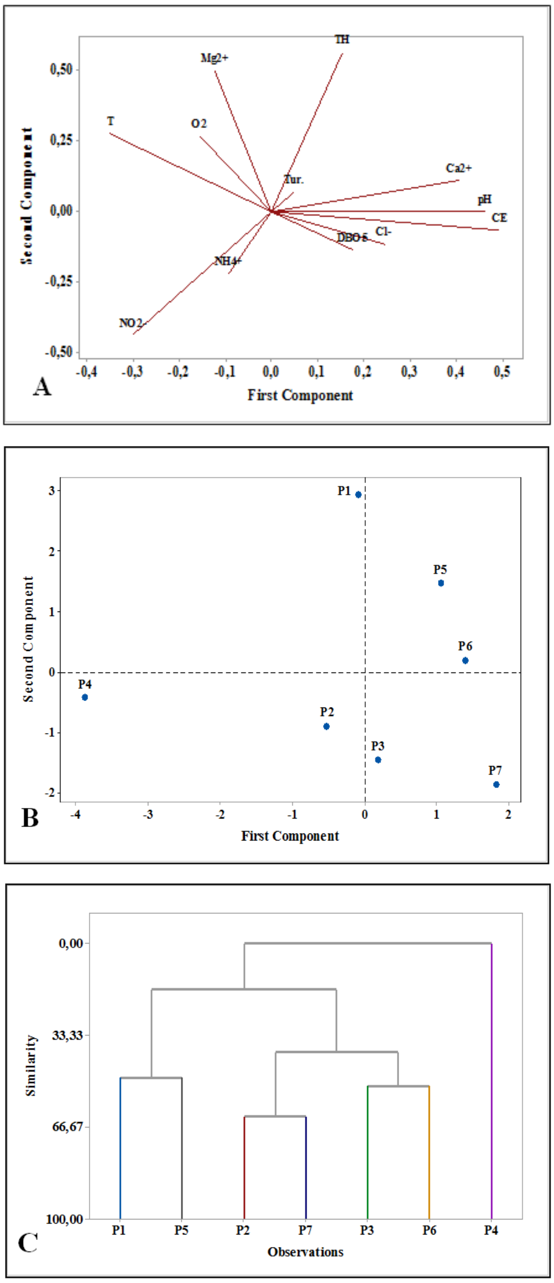


**Fig. 3.** Graphical Representations of Statistical Analyzes. A: Graphical representation of the physico-chemical variable points in the factorial plane F1-F2. B: Graphical representation of individual points (wells) in factor plane F1-F2. C: Dendrogram representing the regrouping of the 7 sampled wells, obtained using the simple link and the square distance of pearson.

*Results of the principal component analysis (PCA) of the bacteriological parameters of the wells*

Principal component analysis (ACP) was applied to the matrix of correlations obtained from the three reduced bacteriological variables taken in pairs. The calculations carried out give the characteristics of the 3 principal axes, the first two of which have an eigenvalue greater than unity or the average contribution of the different variables, ie the arithmetic mean of all eigenvalues. These two first axes are retained and will be used later to study the distribution of individuals (wells) and variables in two-dimensional planes.

Table 8 gives the eigenvalues, the percentages of variation explained by each of the 2 axes selected, as well as the cumulative percentages. It is clear that the first axis explains 55.2% of the total variation of the initial variables, the first 2 axes together account for 89.4%. So these 2 axes or synthetic indices summarize as best the information provided by the 3 initial variables.

The ACP showed that Enterococci (Ent.) Contribute positively to the expression of axis 1, which of the variability captured. The second component, with the variability captured, shows the total coliforms (CT) which contribute negatively to the expression of this axis (Fig. 4A). The hierarchical classification of the wells on the basis of the bacteriological quality of these waters enabled us to distinguish three different groups (Figs 4B, 4C):

Group 1: It contains well P6, which contains water of poor bacteriological quality, characterized by total coliform (CT), faecal coliform (E. coli), and very high enterococci (Ent.).

Group 2: It contains the well P2, which presents water of bacteriologically good quality. This well is characterized by the presence of germs indicative of fecal pollution.

Group 3: This group unites all the wells following P5, P4, P7, S3 and P1, whose waters are of good quality. This well is characterized by absence of germs indicative of fecal pollution.

**Table 8.** Eigenvalues and percentages expressed for the main axes.

| Parameter | Axis 1 | Axis 2 |
|---|---|---|
| Own values | 1,6570 | 1,0251 |
| Percentageexplained in% | 0,552 | 0,342 |
| Percentage cumulative in% | 0,552 | 0,894 |

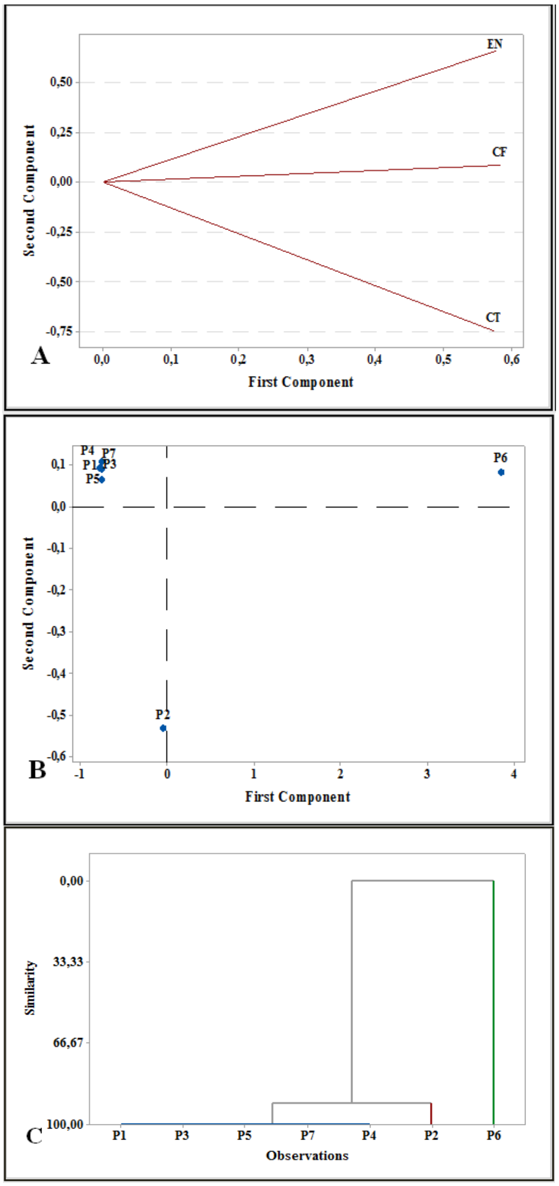


**Fig. 4.** Graphical Representations of Statistical Analyzes. **A:** Graphical representation of the bacteriological variable points in the factorial plane F1-F2. **B:** Graphical representation of individual points (wells) in factor plane F1-F2. **C:** Dendrogram representing the regrouping of the 7 sampled wells, obtained using the simple link and the square distance of pearson.

## Discussion

*Physico-chemical analyzes*

The groundwater temperature varies between 13.8 °C and 21.5 °C, with an average of 17.73 ± 0.69 °C and remains linked to climatic conditions. Water pH values range from 6.03 to 7.75 pH units with an average of 7.22 ± 0.08 and remain a highly sensitive parameter to various environmental factors, as it depends on changes in temperature, salinity and rate Dissolved $CO_2$ and the geological nature of the land that houses the water (Azami Hassani, 1996), the electrical conductivity of groundwater in the region varies between 99.30 and 883 µS.cm-1 with an average of 386, 23±62.85µs/cm. Considering the characteristics relative to conductivity according to EU/OMS (2007), which makes it possible to note how the water conducts the electric current and the approximate evaluation of the minerals in the waters; This classification according to the OMS shows the existence of two categories of water analyzed that do not comply with 86% of the mineralized waters for wells P1, P2, P3, P5, P6 and P7 of values below 150 µs/cm and 14% of the moderately mineralized waters for P4. With values greater than 800µs/cm.

The turbidity of the waters of the area, which gives direct access to the measurement of the dynamics of particulate pollution in the wells analyzed, has clear colorless waters that remain below 5 NTU (JORA, 2011; OMS, 2004). Which varies between 0 and 1 NTU with an average of 0.08±6.03 NTU. According to WHO (1994), whose values $O_2$<3mg/l it recommends, the surface waters of these wells are poor with dissolved oxygen values between 0.65 and 1.73 mg/l with an average of 1.46±0.05mg/l. The total hardness of groundwater in the region varies between 174 and 440mg / l of CaCO3, an average of 289.86±16.97mg/l of CaCO3 not exceeding Algerian standards of 500mg / l CaCO3 ( JORA, 2011). It should be noted that for water intended for human consumption, OMS does not recommend value but indicates that high hardness may cause deposits while low hardness may cause corrosion problems.

It can be considered that a water has a high hardness if it is greater than 250 mg/l of CaCO3. This indicates that the waters of the wells of the Larbi Ben M'hidi area are on the whole very harsh except for the wells P4 and P7 respectively 249.33 and 248mg/l of CaCO3 which are calcareous. Calcium is usually the dominant element in drinking water. For the studied waters the calcium values found are between 65 and 377mg/l, with an average of 148,33±14,30mg/l. These results comply with Algerian standards which recommend a concentration of 200 mg/l as the maximum concentration. The magnesium ion is a significant element of the hardness of the water, its content depends on the composition of the sedimentary rocks encountered (dolomitic limestones, dolomites of the Jurassic or the middle triassic) (Rodier, 2005). Our waters have magnesium contents ranging from 27 to 292mg/l, with an average of 144.52±15.24mg/l, which is much lower than the value recommended by the regulations of our country, or Requires a maximum concentration of 150mg/l. The chloride content of the waters is extremely varied and related mainly to the nature of the lands traversed. The big disadvantage of chlorides is the unpleasant taste that they communicate to water from 250 mg/1. The analyzed water content is between 49 and 52mg/l. It remains in conformity with the Algerian standards country which fixes a maximum admissible concentration of 500 mg/1 (JORA, 2011). Nitrites are the indicators of pollution, they come either from incomplete oxidation of ammonium or from a reduction.

on of nitrates. The recorded nitrite values for our wells studied do not exceed 0.02mg/l which meets the standards not exceeding a maximum value of 0.1 mg/l. Deep water can charge ammonium by reducing nitrates under the action of bacteria. Our country's regulation sets a limit of 0.5mg/l. The content found in our waters is less than 0.09mg/l, it is in the prescribed standard. The biochemical oxygen demand values for our wells studied do not exceed 2mg/l, which meets the standards that do not exceed the maximum value of 3mg/l. (JORA, 2011).

*Bacteriological analyzes*

Groundwater is the vector of pathogenic or non-pathogenic microorganisms. When the self-purifying power of the soil is very efficient, practically ground water is deprived of it under natural conditions. A particular problem is posed by the Karsticaquifers in which self-purification is weak, nil (Castany, 1982). Water from shallow aquifers is often contaminated after heavy precipitation (Rodier *et al.*, 2009).

Concerning the waters of the wells of the region of Larbi ben M'hidi, the bacteriological analyzes made it possible to deduce the following results:

An infestation of a few wells whose concentrations ranged from 0 to 1400 CFU/100ml with an average of 234.38±103 CFU/100ml for total coliforms, from 0 to 460 CFU/100ml with an average of 36.71±37.7 CFU/100ml for faecal coliforms and 0-1400 CFU/100ml with an average of 132.62±82.5 CFU/100ml for enterococci. In the set of seeds sought, it was found that none of the 07 wells was of acceptable bacteriological quality. Pollution factors depend on major problems related to well hygiene. The high concentration of bacterial flora depends on the nutrient richness of human and animal releases and temperature (Rejsek, 2002).

*Statistical analyzes*

*ACP of the physico-chemical parameters of the wells*

Principal component analysis (ACP) was applied to the matrix of correlations obtained from the twelve reduced centered physico-chemical variables taken two by two. The calculations carried out give the characteristics of the 5 principal axes, the first 3 of which have an eigenvalue greater than unity or the average contribution of the different variables, ie the arithmetic mean of all the eigenvalues. These first three axes are chosen and will be used later to study the distribution of individuals (sinks) and variables in two-dimensional planes. The numerical results of the ACP show that the first component contrasts ($Ca^{2+}$, pH and CE) with positive coordinates, with T and $NO_2^-$ having a strong contribution on the negative side. The second component opposes DT and $Mg_2^+$, which contribute positively to the expression of this axis. In contrast to $NH_4^+$ $DBO_5$ which negatively correlate with this axis.

The hierarchical classification of the wells on the basis of the physicochemical quality of these waters allowed us to distinguish, P4 which has water of poor physicochemical quality, characterized by a high level of $NO_2^-$ and also of $NH_4^+$. This could be explained by the human and agricultural activities neighboring this water point, and (P6, P3) whose waters are of medium physicochemical quality, and (P7, P2) which has water of good physicochemical quality, and (P5, P1) whose waters are of medium physicochemical quality but characterized in very high magnesium ions.

*ACP of the bacteriological parameters of the wells*

The ACP showed that Enterococci (Ent.) Contribute positively to the expression of axis 1, which of the variability captured. The second component, with the variability captured, shows the total coliforms (CT) which contribute negatively to the expression of this axis. The hierarchical classification of the wells on the basis of the bacteriological quality of these waters enabled us to distinguish: P6 which contains water of poor bacteriological quality, characterized by total coliform (CT), faecal coliform (E. coli), and very high enterococci (Ent.). And P2 which presents water of bacteriologically good quality. This well is characterized by the presence of germs indicative of fecal pollution. And (P5, P4, P7, S3 and P1) whose waters are of good quality. This well is characterized by absence of germs indicative of fecal pollution.

**Conclusion**

This study allowed us to conclude that the bacteriological and physicochemical contamination of well water in some Larbi Ben M'hidi camps varies from one group to another. The main cause of this pollution is anthropogenic activities which continue to present a major risk for humans and their environment, in particular for water resources.

This study also showed the importance and usefulness of univariate and multivariate statistical analysis techniques in obtaining information on the hygienic quality of water and in preventing all kinds of pollution originating from domestic, agricultural activities and/or industrial sectors.

The results of this study will be of great interest to the healthcare services which will lead to the implementation of preventive and curative actions in order to avoid possible serious health risks. They will also enable decision-makers to set up information, education, communication and awareness-raising (IECS) policies and programs for the rationalization, preservation and enhancement of our water resources, Aligning with the recommendations of sustainable development.

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